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[Plate II]

SYNOPSIS OF THE PRE-VINDHYAN GEOLOGY OF RAJPUTANA

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SYNOPSIS OF THE PRE-VINDHYAN GEOLOGY OF RAJPUTANA.[1]

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(*Read January* 8, 1935.)

(Plate II.)

Contents.

Introduction.

It seems probable that on the day on which this paper is read I shall complete the survey of which it treats and shall be leaving Rajputana, almost exactly 27 years after I first entered it. Except for a few seasons in Burma during and just after the War, and two cold-weathers spent at Headquarters, all my field-seasons since 1908 have been in Rajputana, my first, 1907, having been in Central India.

As it may be some little time before the more recent results of this survey can all be published, it is most opportune that the National Institute of Sciences has honoured me by an invitation to give at the Inaugural Meeting a summary of the work which my colleagues and I have now brought to completion.

I would here tender my grateful thanks for their co-operation to all associated with me in the work.

A list, not a full bibliography, of the more important papers on the geology of Rajputana, is appended.

Rajputana is divided geologically and physiographically into four regions :—

I. In the east the Vindhyan plateau and the little altered Archæans in the neighbourhood of the Great Boundary Fault. The Deccan trap of Malwa just enters the south-east corner of the province.

II. The central plain of Aravallis and pre-Aravalli gneisses.

III. The hilly belt occupied largely by the synclinorium of the Delhi system.

IV. The sandy western plains with scattered outliers of the Malani volcanics, Vindhyans, Mesozoics and Eocene resting on an almost entirely concealed basement of Aravallis and gneiss.

[1] Published with the permission of the Director, Geological Survey of India.

 [Published May 15, 1935.

This paper is concerned principally with the central plain (II)[1] and the hilly belt (III) surveyed since the Great War.

Politically it comprises parts of the British district of Ajmer-Merwara, Mewar (Udaipur State) and Marwar (Jodhpur State).

The present geological survey of Rajputana was originally undertaken as a revision of C. A. Hacket's work.

Between the publication of Hacket's first paper in 1877, and the other in 1881, his views underwent a vital change with regard to the succession. It is not necessary to go into this here, as the question has been fully discussed in my memoir (1917) on North-Eastern Rajputana. It was established that the views of his 1877 paper were correct, and that he had subsequently been led into error by a certain lithological similarity of part of the Ajabgarh series to the Aravallis, and by the prevalence of inversion and by the much more complex structures in the country treated of in his 1881 paper.

It was obvious, too, that the somewhat meagre descriptions of the geology given in these two papers were quite incommensurate with the size, complexity and importance of the area. In Hacket's day also the microscopical study of rocks was in its infancy. His maps, though accurate and carrying sufficient detail in north-eastern Rajputana, afterwards became merely broadly lithological,—the results of rapid traverses. Ultimately this survey has passed southward beyond the limits of Hacket's mapping.

Part of the work done in Rajputana in the last twelve years, *i.e.* south and west of Ajmer (26° 30′ : 74° 40′), is included in a memoir by Mr. B. C. Gupta, 'The Geology of Central Mewar', which has just been published. It describes the central plain of Rajputana (II) and deals principally with the Aravallis and the pre-Aravalli gneisses.

I have in preparation a memoir which will be devoted essentially to the great synclinorium of the Delhis (III), but will include tracts of the Aravallis and older gneisses on either side of it. The southern end of the synclinorium has been described in Mr. C. S. Middlemiss' memoir on 'The Geology of Idar State', in Dr. A. L. Coulson's memoir on 'The Geology of Sirohi State' and in Mr. N. L. Sharma's note on the geology of Danta State. Idar and Danta States, though not in Rajputana, immediately adjoin it, just over its southern boundary.

The little altered Archæans of the east (I) are discussed in my memoir ready for the press, on south-eastern Mewar, in Dr. Coulson's paper on the 'Geology of Bundi State', and in my memoir, 'Gwalior and Vindhyan Systems in South-Eastern Rajputana'. These three accounts are also largely concerned with the Vindhyans, and describe a continuous belt of country (I).

References are made to Malani and other rocks older than the Vindhyans (IV) in my paper on the 'Vindhyans of Western Rajputana' which should be read in conjunction with Mr. T. D. LaTouche's 'Geology of Western Rajputana'.

The only portions of Rajputana as yet geologically unsurveyed in detail are the areas of Mesozoics and Eocene in the north-west; traverses of these have been made, but adequate topographical maps have hitherto not been available; these are now in preparation.

A tabular scheme of the formations older than the Vindhyans is given.

The chief new features in the unpublished results are as follows:—

The Bundelkhand gneiss and a great complex of mixed gneisses have been proved to be older than the Aravalli system.

The Aravalli system is shown to include what were formerly tentatively called Gwaliors

[1] Roman numerals in brackets refer to the four physiographical regions of Rajputana.

in south-eastern Rajputana (Heron, 1922), and it is at least possible that the Gwaliors of the type area near Gwalior City (26° 14′ : 78° 14′) are also unaltered Aravallis.

The Aravallis have been found to include near their base in places a great succession of contemporaneous volcanics, and their probable topmost beds are a thick series of quartzites; there are also other quartzite, shale and grit formations, with a thin contemporaneous lava-flow, succeeding the Aravallis proper with a slight or uncertain unconformity, but not of sufficient importance to separate them from the latter; they are recognizable only in the area of little altered Archæans south of Chitor (24° 54′ : 74° 41′).

The Raialo limestone and quartzite have been separated from the Delhi system, and made into a separate series, with a biotite-schist formation succeeding the limestone upwards.

There are thus three major erosion unconformities,—at the base of the Aravalli system, at the base of the Raialo (27° 5′ : 76° 17′) series, and at the base of the Delhi (28° 39′ : 77° 18′) system.

The Delhi system has a twofold division into the Alwar (27° 34′ : 76° 40′) and Ajabgarh (27° 11′ : 76° 21′) series and the latter into three groups.

There are granites, with their associated vein-rocks, of at least four different ages.

Pre-Aravalli, the Bundelkhand gneiss, and probably several of distinct ages in the banded gneissic complex.

Post-Aravalli and pre-Delhi, an acid granite.

Post-Delhi, the Erinpura (25° 8′ : 73° 3′) granite, which, with its pegmatites, extends throughout the synclinorium, including those of north-eastern Rajputana and Jaipur.

The Malani granites (Jalor and Siwana) are much younger than the Erinpura granite, and they and their associated rhyolites are quite distinct from it.

Basic and ultrabasic rocks intrude all the formations.

A new suite of basic and ultrabasic rocks, older than the Malani series but younger than the Erinpura granite, has been discovered by Dr. Coulson in Sirohi (24° 53′ : 72° 52′) State. The youngest of all the igneous rocks is dolerite, excluding of course the Deccan trap.

Bundelkhand Gneiss.

Typically this is a non-porphyritic granite of medium and fairly uniform grain, unfoliated, of a reddish pink colour. The quartz has a faint violet opalescence, and the felspars are much decomposed and replaced by kaolin, sericite, calcite and quartz. Ferromagnesian minerals are scarce, and comprise both biotite and green hornblende, but as a rule only ragged shreds of them remain, the bulk having been altered to chlorite and epidote. Veins of red aplite or microgranite are common, consisting of quartz and orthoclase, with microcline and hornblende in small amounts, and showing obscure granophyric and micro-pegmatitic texture. True pegmatites are very rare, but in the south of the area, near Katai (24° 28′ : 74° 35′) and Khardeola (24° 29′ : 74° 31′) large masses of a coarse-grained modification are present, in which large saussuritised felspars lie in a granophyric and graphic intergrowth of felspar and quartz.

All over its area of exposure the Bundelkhand gneiss is penetrated by dykes of dolerite, a foot to ten feet in width, without any particular direction and seldom ramifying. It is also traversed by less numerous but larger reefs of white quartz, sometimes as much as a mile in length, which stand up as prominent scenic features.

As far as the typical rock is concerned, the term 'gneiss' is, in the strict sense, a misnomer, as conveying an idea of foliation. In Bundelkhand itself, it is stated, foliation is seldom

TABLE OF FORMATIONS

Jodhpur. Memoir, Geological Survey of India, XXXV, Pt. 1. Records, Geological Survey of India, LXV, Pt. 4.	*Mewar, Ajmer-Merwara* (Main Syncline).	Unmetamorphosed rocks of *Chitor, Nimbahera* and *Sadri.*	Great Boundary Fault	*Jaipur.* Records, Geological Survey of India, XLVIII, Pt. 4 and LIV, Pt. 4.	*Alwar.* (North-Eastern Rajputana), Memoir, Geological Survey of India, XLV, Part 1.
Vindhyans of Western Rajputana. Malani volcanic series.		Upper Vindhyans. 'Semri series' (Lower Vindhyans).			
	Delhi System. 'Calc-gneisses' 'Calc-schists' Phyllites, biotite-schists. Quartzites. Basement arkose grits.	Sawa shales and grit.	Jiran sandstone.	Ajabgarh series. Alwar series.	Ajabgarh series. Hornstone breccia. Kushalgarh limestone. Alwar series.
Raialo (Makrana) marble, limestones of Ras. Unconformity not seen.	*Raialo Series.* Garnetiferous biotite-schists. Raialo (Rajnagar) marble. Local basal grit.	Raialo (Bhagwanpura) limestone.			Raialo limestone. Raialo quartzite.
Shales (Sojat). Schists of Godwar. Unconformity not seen.	*Aravalli System.* Phyllites, cherty limestones, quartzites and composite gneisses. Basal quartzites, grits and local conglomerates. Local thick volcanic series.	Khardeola and Kanoj grits, Badesar quartzites. Vague unconformity. Ranthambhor quartzites. Shales and cherty limestones. Basal quartzites and grits.	Binota shales.	Quartzites and schists of Baonli—Awan ridge and Beelun, Biana and Lalsot hills. Volcanics of Basi. Schists of Rajmahal.	Limestones and schists of Baswa and Rajgarh. Quartzite and conglomerate of Rowasa.
Grey homogeneous gneiss.	Banded gneissic complex.	Bundelkhand gneiss.		Gneissic granite of Karela and Ganor.	

well developed, the rock being very commonly to all appearance perfect granite.[1] In this granitoid characteristic the eastern portion of the Rajputana exposures agrees with the Bundelkhand gneiss of Bundelkhand. Both in hand-specimens, in the field and under the microscope, the rocks of the two areas are markedly similar, and their remarkable homogeneity and invariability are points in common, as are the associated quartz reefs and basic dykes. Although separated from Bundelkhand by the breadth of the overlying Vindhyans, a distance of 270 miles, there is no doubt that this granite is an extension of the Bundelkhand gneiss.

Passing to the west, a transition takes place to grey foliated gneiss, so unlike the original granite that their identity would not have been suspected had they not been seen to grade into each other in good sections on the Berach river, a mile above its confluence with the Bagan river (24° 47′ : 74° 32′). Where the granite first becomes foliated, the felspar loses its reddish colour and becomes greenish grey, and sericite and chlorite are developed from the felspar and ferromagnesians; the final product is a 'flaser-gneiss' with strong foliation, interrupted with knots of quartz and comparatively unaltered felspar, the latter sometimes retaining its original pink colour. This passage from granite into gneiss towards the west is in accordance with the increase of metamorphism in the adjoining Aravalli sedimentaries from east to west.

All that we know with certainty regarding the age of the Bundelkhand gneiss and the banded gneissic complex is that the Aravallis rest with a clear erosion unconformity upon both of them, but their mutual relationship cannot be settled, for a broad band of Aravallis conceals their junction.

Banded Gneissic Complex.

In its great variability from point to point, and the scarcity of anything which can with any great certainty be called an altered sediment, this complex is characteristic of the older Archæans the world over.

In the south of Mewar, where it is best seen in immense spreads of excellent exposures, it is a bewildering and intimate intermixture, complicated by appearances of mutual intrusion and by shearing and foliation. The oldest members of the complex may possibly be the much foliated biotite- or chlorite-schists, which occur sparsely, and which may conceivably represent some form of primitive sediment largely composed of igneous debris. No considerable areas of this unmixed schist are met with in the south; except for xenoliths, streaks and patches, all has been removed or transmuted by magmatic stoping and assimilation. The resulting composite gneiss shows sinuous alternations of dark biotitic lenticular patches and streaks with those of granitic composition. This combination passes, by increase in the granite component, into gneissic granites, which represent portions where the invading magma has completely supplanted the original schist. The predominant rocks are granites and granite-gneisses, which intrude the schists and form with them composite gneisses by interfoliar injection; they seem to be the earliest *undoubted* igneous rocks in the complex. No intrusive contact has anywhere been detected between unfoliated granite and granitic gneiss, and instances of the two grading into each other have frequently been seen. It is concluded that the bosses of granite, in which the rock is little foliated, represent solidified 'cisterns', and that the foliated and banded gneissic veins are apophyses from them. Pegmatites and aplites, closely related to the granite, occur in it as veins, and also invade the

[1] 'Manual of the Geology of India', 2nd edn., p. 26.

schists and the granitic gneisses, forming with them composite gneisses. They probably belong to various ages. Epidiorites and hornblende-schists, representing basic intrusives, occur in abundance, and are penetrated by the aplites and pegmatites. They occupy, for the most part, an intermediate position in the sequence of intrusion, invading the granite and gneissic granite, and in their turn cut by pegmatite and aplite. For instance, the coarse post-Delhi pegmatite, connected with the Erinpura granite and containing muscovite, tourmaline and beryl, invades in places the gneissic complex, as well as the pre-Aravalli pegmatites. Quartz veins have probably accompanied all the acid intrusives, and have had a wide range in their period of intrusion; they may be regarded as persisting as the last phase of igneous activity, cutting all members of the complex.

The above description refers generally to the banded gneissic complex in the southern parts of Mewar, where it attains its greatest complexity, and in the field is very distinct from the Aravallis which rest on it with a clear erosion unconformity, accompanied by thick conglomerates and a great series of contemporaneous basic lavas. Towards the centre of Mewar, *e.g.* east of Udaipur City (24° 33′ : 73° 42′), the gneisses are somewhat simpler in composition, and may be described as composite gneisses, essentially a mixture of biotite-schist (with hornblende-schist and chlorite-schist in subordinate amount) and white or pink aplite and microgranite injected along the foliation, with intrusive bodies, of all sizes, of grey foliated biotite-granite.

The locality where least intrusion has taken place in this basement complex appears to be the embayment in the margin of the Delhis west of Antalia (25° 13′ : 73° 46′). Here the predominant rock is coarsely flaky biotite-schist, crowded in places with garnets, and with quartz and felspar in small discontinuous lenticles and streaks. This may be a form of primitive sediment. There is also much hornblende-schist in great sill-like sheets. In the apex of this embayment, south-west of Antalia, the gneisses are much more heterogeneous, granitoid, 'augen', and banded types occurring.

This is their general character over the great plain of north Mewar and Ajmer—dark schists and granulites, often garnetiferous, with intrusions, of all sizes, of a dark-coloured porphyritic biotite-granite, varying from granitoid to strongly banded, resulting in the formation of composite gneisses, and, most typically, what has been called 'bead-gneiss', in which felspar phenocrysts are strung out along lines in the dark biotitic matrix.

The banded gneisses occupy the western portion of the central plain of Mewar, swinging east into Banswara State. A large oval inlier, about the centre of which is Sarara ki Pal (24° 9′ : 73° 50′), lies in the south of Mewar, and extends south across the Som river into Dungarpur State. (The remainder of Banswara and Dungarpur is occupied by the Aravallis, with outliers of Deccan trap.)

Another type of ancient gneiss is that found to the north-west of the great Delhi synclinorium, in the plains along the north-west foot of the Aravalli range. This is a grey ('pepper and salt') rather fine-grained rock of granitic composition and texture, homogeneous as a rule, but sometimes slightly porphyritic and foliated. The basal conglomerate of the Delhi system rests upon it with an erosion unconformity and is to some extent composed of its debris, but its relation to the Aravallis, which to the north-west of the range occur only in a few exposures isolated in alluvium and at a considerable distance away from the gneiss, is not known. It may be older than the Aravallis, or it may be intrusive in them, but it is unlike the granite which invades them on the other side of the Delhi synclinorium and the range. It is intimately associated with the crystalline limestone near Ras (26° 19′ : 74° 11′) which is supposed to be the same as the Raialo limestone, but the sections showing the contact of granite gneiss and limestone are equivocal and give no clear evidence of either

intrusion or unconformity. To the south-west it becomes greatly intruded by the Erinpura granite and ultimately is completely replaced by it.

That the banded gneissic complex was originally a sedimentary formation is shown by two oval domes of massive quartzite. which rise from amidst the mixed gneisses north-west and west of Amet (25° 19′ : 73° 58′) and are respectively seven square miles and one square mile in area. On all sides the quartzites dip quaquaversally and concordantly under the surrounding gneisses and both domes rise on separate but parallel anticlinal axes traceable for miles in the gneisses. This indicates that the gneisses, before their wholesale intrusion and replacement by many forms of igneous rock, were originally a pelitic formation, now represented by their biotite-schist constituent, and were underlain by these thick quartzites, just as both the Aravalli and Delhi systems have at their base quartzites and become pelitic above the quartzites.

Aravalli System.

The Aravalli system is an immense thickness of argillaceous rocks which vary in their degree of metamorphism, passing from east to west, from shales through slates and phyllites, to fine mica-schists with garnet and magnetite. In certain areas, through *lit-par-lit* injection by acid granite magma, composite gneisses have been produced, consisting of alternating pale quartz-felspar and dark biotite layers, but on the whole igneous intrusions other than white quartz veins are not particularly common in the Aravallis.

Impure argillaceous and ferruginous limestones occur in subordinate amount, and are often sandy, or seamed with quartz veins, probably recrystallised chert. They occur in two facies. In one, certain broad belts of Aravalli phyllites carry great numbers of lenticles of ferruginous limestone up to a few feet in length, *e.g.* in the Aravallis of Bundi (25° 27′ : 75° 30′) State and eastern Mewar; in the other, as around Udaipur City, great deposits of black limestone, many hundreds of feet in thickness, and several miles long, occur as lenticles on a large scale. There are, however, wide tracts of the Aravallis devoid of limestones, as in the country to the west of Udaipur City, between it and the base of the Delhi system. In the last-mentioned area massive quartzites, intricately folded, take the place of limestones; elsewhere quartzites are poorly developed, except in the basal formation.

As the phyllites as a rule show no stratification but only foliation, the folding of the Aravallis can be deciphered only by the quartzites, and judging by them, must be very complex and complicated by shearing, thrust-faulting, and plastic flowage.

The basal beds of the Aravallis are thin but fairly continuous arkose and gritty quartzites, resting upon the Bundelkhand gneiss and the banded gneissic complex. In places wedge-faulting gives a deceptive appearance of the gneiss being intrusive into the Aravallis, but there is never any local alteration of the Aravallis at the junction, and the cumulative effect of the evidence along the many miles of contact examined is that there is no doubt about the erosion unconformity.

Usually the basal quartzites are succeeded immediately by shales or phyllites, but in two areas, near Delwara (24° 47′ : 73° 45′) and near Natharia ki Pal (24° 14′ : 73° 47′) a great thickness of volcanic effusives is accumulated; at Delwara they are amygdaloids and hornblende-schists, representing basic lavas and tuffs, at Natharia ki Pal they are banded garnetiferous hornblende-schists (tuffs) with a coarse volcanic agglomerate at the base. At the latter locality the volcanics pass upwards conformably into a great series of conglomerates, the only large development of conglomerates in the Aravallis, and these again pass up into massive quartzites.

Intrusive igneous rocks in the Aravallis comprise granites and ultra-basics. The latter are largely developed in the neighbourhood of Rakhab Dev (24° 6′ : 73° 42′),—talc-serpentine-chlorite rocks, which have been described by Dr. P. K. Ghosh (1933); they are found also to the south in Dungarpur and Idar States (Middlemiss, 1921).

The granite is an acid, fine-grained type (aplo-granite) forming bosses with very irregular margins and satellite intrusions, showing all the criteria of intrusion, north-west and south-east of Udaipur City, and also producing, by *lit-par-lit* injection of the Aravalli mica-schists, a banded composite gneiss, which runs as a broad band from near Udaipur City south-eastwards past Salumbar (24° 12′ : 74° 5′) into Dungarpur State.

Another type of granite forms four bosses near Salumbar, with veins penetrating the composite gneiss above-mentioned in which the bosses lie; this is rather coarse, porphyritic and unfoliated, with abundant biotite. It resembles the post-Delhi Erinpura granite, and as it is younger than the aplo-granite which forms the Aravalli composite gneiss, it is possible that it represents deep-seated intrusions of the Erinpura granite.

Epidiorites and hornblende-schists, metamorphosed ancient basic rocks, and the much newer post-Delhi dolerite, also invade the Aravallis, but are much scarcer than in the Delhis or the pre-Aravalli gneisses.

Aravalli System, Unmetamorphosed, Eastern Mewar.

The unaltered, or little altered, Aravallis near Chitor (24° 54′ : 74° 41′), in the vicinity of the Great Boundary Fault of Rajputana, call for special notice. To the east of the fault they have been given the local name of the 'Binota (24° 32′ : 74° 34′) shales', as they are separated from the undoubted Aravallis to the west by the fault. They are olive and brown shales, variegated with purple, sandy and micaceous, or soft and flaky, carrying thin ferruginous bands, and large concretions of ferruginous sandy clay, usually somewhat flattened. They generally lie nearly horizontally or with low rolling dips.

Their base is not seen, and to the east they are succeeded unconformably by the Jiran sandstone, the basal beds of the Vindhyans, and the Deccan trap. Except for their low degree of alteration, their lithological facies is so similar to that of the Aravallis adjoining them to the west of the fault that there is little doubt of their identity.

To the west of the fault the Aravallis consist predominantly of slates, ferruginous and siliceous limestones and intrusive dolerite, the latter being the same as that intruding the Bundelkhand gneiss, but distinct from the later post-Delhi dolerite occurring in the Delhi synclinorium, and, of course, from the still later Deccan trap. When least altered they differ little from shales except in having a cleavage which causes them to distintegrate into splinters rather than into thin bedding plates. As they are followed westward across the strike, cleavage in them becomes more distinct, and about longitude 74° 30′, phyllites, with silvery and wrinkled foliation faces and numerous large quartz veins, represent the local state of metamorphism. Here a belt of Bundelkhand gneiss intervenes, and on the western side of it come dark mica-schists with occasional thin bands of hornblende- and chlorite-schists. These contain small garnets, increasing in quantity towards the west, with magnetite, staurolite, chiastolite and some kyanite in their phase of maximum metamorphism. The thin interbedded quartzites and limestones also show progressively increasing metamorphism, though, owing to their composition, it is not as distinct in them as in the argillaceous rocks. The dolerite becomes epidiorite and hornblende-schist. West of the fault the dips, as shown by the limestones and quartzites, are always high. The basal beds are thin quartzites, with grits and

arkose resting upon the Bundelkhand gneiss, or sometimes the slates themselves lie directly on the gneiss. The old pre-Aravalli surface of weathering is sometimes seen, discoloration and disintegration extending a few feet into the gneiss from the unconformity junction.

In the vicinity of Ranthambhor (26° 1′ : 76° 28′) and Sawai Madhopur (26° 0′ : 76° 24′) in Jaipur State (Heron, 1922, pp. 133–138) great thicknesses of reddish sandstone quartzites are exposed, and appear to be the highest representatives of the Aravalli system (then called the Gwaliors). The same rocks occur, again as synclines, near Mandalgarh (25° 15′ : 75° 8′), Hora (24° 47′ : 74° 32′) and Bari Sadri (24° 25′ : 74° 31′) in Mewar, with the same relationship of apparent conformity to the underlying Aravalli shales. Below the base of the sandstones near Mandalgarh purple grits are interbedded with the slates and contain angular fragments of the latter. The shales however pass up quite conformably into the quartzites, and it is impossible to decide upon any particular horizon in the grits at which to place an unconformity. The pebbly beds, and the unrounded, and therefore untransported, pieces of shale, denote shallow water conditions, with local erosion, but there is no evidence of a break in the succession.

The Hora syncline shows 1,500 to 2,000 feet of pinkish-purple quartzites, thick-bedded, frequently gritty, and with small scattered pebbles of quartz.

The Bari Sadri syncline is much larger, about twenty miles long and five miles wide, and extends southwards into Partabgarh State. The quartzites are similar to those of Hora, and show false-bedding and ripple-marking; towards the centre of the syncline they are distinctly pebbly. They pass downward conformably into slates and phyllites.

At Mandalgarh, as in Jaipur, sills of dolerite are intruded in the Ranthambhor quartzites; at Hora and Bari Sadri they are absent from the actual quartzites but are present in force in the slates immediately underlying.

The Hora and Bari Sadri synclines are isoclines, whereas those of Ranthambhor and Sawai Madhopur and at Mandalgarh are basins; the alteration of the quartzites themselves and of the adjacent argillaceous rocks is in accordance with this, those of Bari Sadri being very similar to the quartzites of Malarna in Jaipur, also believed to belong to the Ranthambhor quartzites (*op. cit.*, p. 140), and like them, abundantly traversed by fine veinlets of white quartz in shatter-cracks, while the argillaceous rocks are slates and phyllites as at Malarna (26° 17′ : 76° 30′), instead of shales as at Mandalgarh, Ranthambhor and Sawai Madhopur.

The little altered Aravalli shales of the Chitor neighbourhood pass to the north-east *along* the strike, past Mandalgarh and through Bundi (25° 27′ : 75° 39′) into south-eastern Jaipur; their lithological similarity and their association with the Ranthambhor quartzites would render their correlation probable, even if they were not on the same strike-continuation.

On my first visit to south-eastern Jaipur I believed that I could trace a gradual increase in the metamorphism of these Gwalior type shales and slates *across* the strike to the north-west into the typical Aravallis; on my second visit, with Hayden, Middlemiss and Vredenburg, I was shaken in my opinion, more perhaps by the weight of their opposition to it than by actual conviction on my part, and classified these rocks as Gwaliors (*op. cit.*, pp. 143-144). Since then, having had access to the wide expanses of them in Mewar, I am convinced that my original opinion was correct, and that the Gwalior-type shales of south-east Jaipur, Bundi and south-east Mewar and the typical Aravalli phyllites and mica-schists are all the same, varying only in their degree of metamorphism.

This raises the problem of the Gwaliors of the type area around Gwalior City, which are isolated by the intervening eighty miles of Vindhyans. I have explained (*loc. cit.*) the general

lithological similarity between the Gwalior-type Aravallis, especially near Hindaun (26° 44′: 77° 4′), and the shales and jaspers of the Ranthambhor beds on the one hand and the Gwaliors of Gwalior on the other. Although the Gwaliors proper do not lie upon the strike-continuation of the Jaipur rocks, but to the east of it, there is at least a possibility that they are a portion of the Aravalli system, and owe their horizontality and absence of alteration to their distance from the Aravalli range belt of diastrophism and their protection by the inflexible mass of Bundelkhand gneiss upon which they lie.

The Khardeola (24° 29′: 74° 31′) grits, a local formation, are present in several disconnected outliers from two miles east of Bhanuja (24° 32′: 74° 30′) south-east to near the southern frontier of Mewar with Partabgarh State, along a zone in which they and the underlying Khairmalia (24° 29′: 74° 35′) amygdaloid lie unconformably on the Bundelkhand gneiss and the Aravalli slates and dolerites, and are succeeded upwards unconformably by the Bhagwanpura limestone (Raialo).

The amygdaloid is a devitrified basic glass with vesicles filled with chalcedony and quartz, associated with lenticular ferruginous sandstones and red and brown cherts. There is no doubt that it is a lava, and as no igneous rocks are found at any higher horizon (except the Deccan trap, of course) in the ancient unaltered rocks of eastern Mewar, the suggestion may be made that it is the effusive representative of the hypabyssal dolerite sills and dykes which traverse the Aravallis and the Bundelkhand gneiss.

The Khardeola grits, which conformably succeed the amygdaloid, are a succession of sandy slates, grits and greywacké, mostly inky purple in colour, interbedded with true shales which are exactly similar to the Aravalli shales. A conglomeratic quartzite, about fifty feet thick, occurs near the base. Exposures are poor, and the resemblance between the shales in the Khardeola beds and the Aravallis makes the drawing of a boundary between them difficult, but the field evidence indicates a slight unconformity between them. There is, however, no reason for referring them to the Delhi system. The Kanoj (24° 45′: 74° 35′) grits and the Badesar (24° 39′: 74° 33′) quartzites occur to the north of the Khardeola grits. Their relation to the main Aravalli system is obscure, but is probably similar to that of the Khardeola grits. The Badesar quartzites have some resemblance to the Sawa grit, though finer in grain, but the Sawa grit is not associated with any rocks like the Kanoj grits.

Raialo Series.

In the survey of North-Eastern Rajputana, I (1917, p. 12) suggested a possible slight local unconformity between the Raialos and the Delhis, but as the sections available were very limited in the direction of dip and both formations dip in the same direction, I did not recognize its magnitude, but placed, as Hacket had done, the Raialo limestone and quartzite at the base of the Delhi system.

When the much more extensive areas of the Raialos in central Mewar became available for study, it was clear that the break between them and the overlying Alwar quartzites at the base of the Delhi system was more profound than had been thought, and was in fact of about the same importance as that between the Raialos themselves and the Aravallis. The Raialos have now been separated from the Delhi system and elevated into a 'series', intermediate in position between the Delhi system and the Aravalli system.

The Raialo series consists principally of a limestone, usually white, about two thousand feet in thickness, with at its base a thin quartzite or sandstone, which is occasionally conglomeratic; the basal sandstone or quartzite is, however, more often than not missing and the

limestone then rests directly on the Aravallis, the Bundelkhand gneiss, or the banded gneissic complex.

A correlation has been made between the widely separated exposures, which I believe to belong to the Raialo series, in central and eastern Mewar and even on the other side of the Aravalli range in Jodhpur State, including the celebrated Makrana (27° 1′ : 74° 42′) marble, depending on the lithological character of the rock and its freedom from intercalation with argillaceous strata, its position as lying directly on the formations below it, or with a thin quartzite at its base, its degree of alteration and admixture with impurities, and the general similarities in bedding, jointing and weathering. It is argued that the correlation is justifiable, though of course it lacks the certainty of fossil evidence; on one point only is there doubt,—the Makrana marble and the others to the west of the range are pure calcium carbonate rocks, while all the exposures to the east of the range, examined either by analysis or by staining methods, prove to be practically pure dolomite.

The Bhagwanpura (24° 30′ : 74° 37′) limestone is the name given to what is believed to be the little altered equivalent of the Raialo limestone in south-east Mewar, running parallel with the Great Boundary Fault from Chitor to its disappearance in the south under Deccan trap. It is fine-grained and not visibly crystalline (in this differing from the typical Raialo limestone, which is usually saccharoidal), in colour creamy or khaki, varying to white, dark grey, brown and even deep crimson. Chert and jasper are common in lenticles, and white quartz in ramifying veins.

Near its base the limestone is conglomeratic in two types, either as angular grains of clear quartz, the residuum of the Bundelkhand gneiss, scattered through the calcareous material, or as a mixture of rounded pebbles of white quartz and of quartzite of all colours, and angular fragments of shale, chert and Bundelkhand gneiss.

The most instructive exposures of the Raialos are in the intricately folded syncline which emerges from below the base of the Delhi system north of Udaipur City (24° 33′ : 73° 42′) and runs north-east past Nathdwara (24° 55′ : 73° 49′) and the Raj Samand lake at Kankroli (25° 4′ : 73° 53′). Here in places the basement bed is a boulder conglomerate up to thirty feet in thickness, elsewhere a thin quartzite. The limestone, usually a pure white crystalline dolomite, an ornamental building-stone of excellent quality quarried at Rajnagar near Kankroli, shows extraordinary variations in its thickness, which must be due to thinning out by 'wire-drawing' in the deep-seated folding of semi-plastic strata. Here alone of all the exposures do we find any Raialo beds higher than the limestone, coarse garnetiferous biotite-schists, cropping out in a wide expanse in the core of the syncline, with a thin quartzite between them and the limestone.

The Raialo series is found also in the Jahazpur (25° 34′ : 75° 17′) and Sawar (25° 46′ : 75° 14′) hills in eastern Mewar, and the limestone alone forms several ridges and plateaus isolated in the pre-Aravalli gneisses east and north-east of Udaipur City and north of the Nathdwara-Kankroli syncline, extending east to near Bhilwara (25° 21′ : 74° 39′). These are considered to be the tips of synclines which have been deeply infolded in the gneissic complex, down to the zone of plastic flowage.

On the north-west side of the Delhi synclinorium, the Makrana marble crops out from the sandy alluvium in narrow ridges over a length of about five miles, the actual thickness being probably much greater than that exposed, only the more resistant beds appearing. The quarries have been extensively worked for three or four centuries, supplying stone for the Taj Mahal and many other Moghul buildings of northern India, as well as the Victoria Memorial in Calcutta, and still support a labour force of about 4,000. The rock is white,

slightly clouded with pale grey, but pure white also occurs, and there are rose-pink and blue-grey varieties.

The group of limestones on the strike-continuation to the south-west, near Ras (26° 19′ : 74° 11′) is much more extensive, being exposed for a distance of fifty miles along the strike, with a width of over a mile. The types of limestone too, are much more varied, perhaps because an almost complete sequence is visible, instead of only a small portion of it as at Makrana. The dominant type is a coarse, white saccharoidal calcite marble, with diopside and white mica; interbedded with it are bands of finer, blue-grey 'sandy' limestone, the 'sandy' appearance being due to knots of secondary felspar, quartz and calc-silicates weathering in high relief; dark calc-gneisses occur sparingly. The pre-Aravalli gneiss laps round the limestone ridges and is exposed in the valleys between them, with a sharp margin between the two, and no sign of conglomerate.

The Raialo limestone is very free from igneous intrusives, perhaps because of the impenetrable nature of the rock. In the Makrana quarries a few dykes of pegmatite are seen, but they are scarce, and elsewhere hardly occur except in the ridges between Kankroli and Sardargarh (25° 14′ : 74° 2′). The garnetiferous biotite-schists which in the Kankroli neighbourhood are believed to overlie the limestone, give, on the other hand, good examples of how various types of gneiss may arise in different ways from the injection of one original rock. Starting from biotite-schist, it may be intruded by large definite dykes of pegmatite, or by clusters of sills with their feeder dykes, to such an extent that little schist is visible, ending in a condition in which the schist is intimately and uniformly injected by multitudinous interfoliar veins of aplite, forming a banded composite gneiss, often highly contorted.

Delhi System, Main Synclinorium.

The intricately folded portion of the Delhi system in Alwar and Jaipur (26° 56′: 75° 53′) has been described in Memoir XLV, pt. 1, and Records XLVIII, pt. 4, and LIV, pt. 4 (North-Eastern Rajputana, Biana-Lalsot[1] Hills and Western Jaipur). This is connected with the main synclinorium in Ajmer-Merwara and western Mewar (Udaipur State) by several straggling ridges of quartzite and arkose conglomerate, representing the Alwar series, in the sandy plains north of the Sambhar (26° 54′: 75° 18′) Lake.

In the northern end of the main synclinorium, north of Ajmer (26° 30′: 74° 40′), exposures are much broken up by alluvium, but as it is followed to the south-west the level of the country rises, and the alluvial mantle becomes patchy. In Ajmer-Merwara the synclinorium consists of two synclines, with a long tongue of the pre-Aravalli gneiss between them. On the outer flanks of the two synclines their unconformable relation to the gneiss is well shown by the great development of boulder and arkose conglomerates at Barr (26° 5′ : 74° 6′) and Srinagar (26° 24′ : 74° 46′), but on the inside, on each side of the medial tongue of gneiss, shearing along the contact has reduced the basement beds to felspathic granulites. The north-west margin of the medial tongue is defined by an important thrust-fault, and this continues beyond the south-west end of the tongue, and brings the two synclines together. The north-western syncline is much more affected by igneous intrusions of the Erinpura granite and of epidiorite than the other, and to the south-west beyond where it passes out of Ajmer-Merwara into Jodhpur (26° 20′: 73° 1′) State (Marwar) these increase to such an extent that the sedimentary rocks composing it are obliterated, and it virtually disappears. Concurrently the other

[1] Biana (26° 55′: 77° 21′), Lalsot (26° 31′: 76° 23′).

syncline narrows, probably by the smoothing out of minor folds, and at the southern tip of the narrow extension of Ajmer-Merwara between Mewar (Udaipur State) and Jodhpur State (Marwar), near Dewair (25° 25′ : 73° 49′), it has its minimum breadth, about six miles. This breadth is maintained for about forty miles along the strike, and in this section the syncline is believed to be simple. In part the decrease in width is due to the Alwar series. quartzites and arkose grits, having for a space almost died out, to reappear again.

South of this the syncline widens owing to additional folds appearing, to a thickening of the Alwar series, and also to deeper folding bringing in the highest beds of the central core. In this syncline also igneous intrusion, principally the Erinpura granite, increases as it is followed to the south-west, particularly in the western half of it. To the east of the main synclinorium are several linearly arranged outliers in which only the Alwar series, basement arkose grits and quartzites, are present, dipping steeply eastwards and inverted under the Aravallis and banded gneisses to the east, to which their stratigraphical relation is that of erosion unconformability, and thrust-faulted to the west against the same formations. They are in fact half synclines, in which only the inverted upper half is present, and the lower half has been removed.

In the main synclinorium the Delhi system has five subdivisions :—

Ajabgarh series	5.	Biotitic limestones = 'calc-gneisses' and calciphyres.
	4.	Calcareous shales and impure limestones = 'calc-schists'.
	3.	Phyllites and biotite-schists.
Alwar series	2.	Quartzites.
	1.	Arkose grits and conglomerates.

The distribution of the five formations between the Ajabgarh and Alwar series is empirical, but is in accordance with the succession in Jaipur and Alwar. The Kushalgarh (27° 26′: 76° 29′) limestone of Alwar, with its closely connected Hornstone Breccia, is missing in Jaipur and also in the main synclinorium.

The Alwar series is irregularly developed. In the northern part of the synclinorium both the strong quartzites and the basement grits are in force, the latter becoming coarse conglomerates at Barr and Srinagar. As a rule they are arkose, the felspathic material being derived from the abundant granite and pegmatite of the underlying gneisses. In the medial part of the synclinorium, taken along the strike where it becomes a simple syncline, the Alwar series dies out, but thickens again in the southern part.

In the southern portion the faulted outliers of the Alwars, which to the east are inverted under the Aravallis and pre-Aravalli banded gneisses from which they are derived, with an erosion unconformity intervening, are arkose and conglomeratic grits, but in the main synclinorium, where the basement beds of the Alwar series rest upon Aravalli phyllites devoid of intrusions other than quartz veins, there is no arkose nor grit and the quartzites are fine-grained. The character of the basement beds is thus directly related to the nature of the land surface from which they were derived, the phyllites and uninjected biotite-schists producing no coarse material, but a fine detritus from which the light aluminous silicates have been washed away, leaving only the quartz. The quartzites are felspathic to some extent, with intercalations of biotite-schist in certain zones.

The lowest division of the Ajabgarhs is usually in the form of a great thickness of biotite-schists abundantly intruded with pegmatite and aplite in great dykes and veins, and in *lit-par-lit* injection. As a rule there is as much igneous material present as sedimentary. The minimum state of metamorphism observed is that of phyllite, and excellent instances are

seen of the transition from phyllite through biotite-schist to composite gneiss formed by the interfoliar injection of biotite-schist with aplite or pegmatite.

The terms 'calc-schist' and 'calc-gneiss' were originally adopted as field terms, but may be retained as they express adequately both the similarities and differences between these two formations. Mineralogically they are much the same, except that in the calc-gneisses there is a notably higher proportion of carbonate, both disseminated and as bands, beds and groups of beds of calciphyre and limestone.

The 'calc-schists' are straightly banded and flaggy, the banding being certainly the original stratification, and is essentially due to the alternation of dark silicates like biotite and actinolite, with pale silicates such as diopside, tremolite and felspars. It is only in the extreme south, in two narrow synclines folded into the Alwar quartzites, that the unmetamorphosed equivalents are seen,—somewhat calcareous shales, and impure black limestones. Usually they are less intruded than the biotite-schists and the intrusions are chiefly in the form of large sills and dykes of pegmatite and veins of aplite, *lit-par-lit* injection being much less common than in the biotite-schists. The intrusion of pegmatite or aplite does not appear to have been the *cause* of metamorphism, for no local effects were ever seen on the margins of pegmatites, and in considerable areas free from pegmatite the calc-schists do not differ from those in pegmatite-riddled tracts. Similarly, pegmatite veins are seen to traverse the biotitic limestones, the less metamorphosed phase of the 'calc-gneisses', without producing local alteration, while highly metamorphosed calc-gneisses may be free from pegmatite. Though not cause and effect, intrusion and metamorphism are no doubt related in that they are both effects of the same cause,—deep folding by which the rocks were brought into the zone of high temperature and pressure within reach of rising granite magma.

The 'biotitic limestones' (or 'calc-gneisses') in their less altered phase are a succession of three thousand feet or more of dark, banded biotitic and siliceous limestones which give rise to a narrow elongated plateau commencing to the east of Beawar (26° 7′ : 74° 19′) and running south-west throughout Merwara, of which it forms the backbone, and passing into Mewar, where it is the raised north-west rim and highest part of the plateau, or eastward sloping plain, of central Mewar. Along the strike the biotitic limestones insensibly grade into calc-gneisses, with no change whatever in elevation and in the characteristic topography to which they give rise. On the other hand, the strip of plateau formed by the combined biotitic limestones and calc-gneisses rises abruptly from the lower tract of calc-schist bordering it on both sides. Between Todgarh (25° 41′ : 73° 58′) and Saera (24° 59′ : 73° 25′) the difference in altitude is about a thousand feet,—a bold bluff rising from the plains of Marwar (Jodhpur State) to the edge of the Mewar plateau, but is usually much less. The lesser elevation of the calc-schists is due to their slabby character and the profusion of pegmatite cutting them, facilitating erosion, in comparison with the more massive calc-gneisses, and in the case of the portion from Todgarh to Saera, to the coincidence with their junction of a line of shearing, a continuation of that mentioned as bordering the tongue of gneiss between the two component synclines of the north-eastern portion of the synclinorium. On the other (south-east) side of the calc-gneisses their boundary with the calc-schists is also in part a zone of shearing, remarkable in its straightness, and producing a narrow shallow trench which was traced from Kumbhalgarh (25° 6′ : 73° 35′) for many miles to the south-west, and ultimately is obscured by intrusions of Erinpura granite along it.

In the calc-gneisses the banding, which is essentially the same as the original bedding, is broader and more variable in composition and in width than in the calc-schists, and is generally vaguer and more irregular. In the calc-gneisses we have bands composed almost entirely of

carbonates (calcite and dolomite) alternating with bands rich in silicates (felspars, diopside and amphiboles) the former bands being more soluble than the latter, which stand out in relief on weathering. They are often characterised by extraordinary contortion.

As a whole, the calc-gneisses are much less intruded by pegmatite than the calc-schists, but in the south-west the Erinpura granite itself invades them on a large scale as the great Erinpura-Abu (24° 35′ : 72° 42′) batholith is approached and finally obliterates them.

Delhi System, Unmetamorphosed.

Among the little altered rocks of eastern Mewar, the Delhi system is very doubtfully represented by two thin formations—the Sawa shales and grit, and the Jiran sandstone. The Sawa shales and grit extend as a narrow strip along the west of the Great Boundary Fault from Chitor southwards to where it disappears under Deccan Trap, and the Jiran sandstone is exposed in the country to the east of the fault. The Sawa grit is unconformable upon the Bhagwanpura limestone, which is believed to be the same as the Raialo limestone, but its relation to formations younger than itself is unknown. The Jiran sandstone rests with a slight unconformity on the Binota shales, believed to be Aravallis, and the basal beds of the Vindhyans in turn are unconformable upon it.

The Jiran (24° 18′ : 74° 54′) sandstone, the 'Delhi quartzite of Hacket' (Hacket, 1881, pp. 293 *et seq.*), forms three synclines and two anticlines, running north and south, and joining to the south to form an irregular plateau in which the beds are practically horizontal. It is overlaid to the north by the Vindhyans, and to the east by the Deccan trap. Its thickness is from one hundred to two hundred feet, of hard, compact, pale grey quartzite mottled with deep purple ferruginous staining, increasing in amount from below upwards, so that the topmost beds are almost unmixed purple. Near Bari (24° 31′ : 74° 39′) the lowest beds are very coarse-grained and have been described by Hacket as conglomeratic sandstone. In no section in the main area of exposure is there any sign of discordance between the Binota shales and the Jiran sandstone, but eight miles to the south, in an isolated group of flat-topped hills, a slight but very clear unconformity was seen, the shales dipping to the west at 5°, under the horizontal sandstone capping.

The Sawa grit is pure white, composed of fragments of quartz and white chert, with conglomeratic bands, and layers of grey sandstone, blotched with brownish purple; false-bedding and ripple-marking are met with, and at one place contemporaneous erosion and deposit. It passes up into pale grey or lavender, almost white, soft, earthy shales, with bands of white chert, a siliceous modification of the shales, intercalated with them at the passage from grit to shale. At the base of the grit also banded chert occurs as the matrix of a conglomerate of chert pebbles. The shales and the grit are about the same thickness, a hundred to two hundred feet each.

Along the Great Boundary Fault the grit and shales dip steeply eastwards towards the fault, or are inverted and dip away from it. In some places they are cut out by the fault or repeated by parallel faults. To the west of the fault is a small plateau composed of the grit, in which the beds have gentle dips. Though the sections are not very clear, the evidence is fairly conclusive that the grit is unconformable upon the Bhagwanpura (Raialo) limestone, but without great discordance.

Followed southwards along the fault the shales die out and the typical white Sawa grit is replaced by a grey quartzite, pebbly in bands, and blotched with purple, probably a development of the grey sandstone banding in the white grit to the north. In the extreme south, where this quartzite is much brecciated, it seems to dip steeply below, or be faulted against,

the Jiran sandstone, which has low rolling dips and forms an extensive plateau to the east. Thus though the Sawa grit and the Jiran sandstone are typically so unlike, there are reasons for believing that they grade into each other.

Their correlation with the Delhi system is doubtful. They do not resemble the Ranthambhor quartzites or the Khardeola grits of the Aravalli system, nor do they particularly resemble the Alwar quartzites at the base of the Delhis, and the discordance between them and the underlying Bhagwanpura limestone and Binota shales seems far less profound than that between the Delhis and the Raialos and Aravallis in the metamorphosed areas to the north and west. On the other hand, here folding has been much less intense, in Aravallis, Raialos and Delhis, and one would not expect unconformities to be so well marked. The Jiran sandstone is most like the Kaimur sandstone, but they are not the same, as the Jiran sandstone is clearly overlaid by the basal beds of the Vindhyans, which are more than a thousand feet below the base of the Kaimur.

Delhi System, Igneous Rocks.

The chief igneous intrusive in the Delhi system is the Erinpura granite, in batholiths, laccoliths and bosses of all sizes, and in wide variations of texture, grain and degree of foliation (Coulson, 1933), and its related pegmatite and aplite. Earlier than the Erinpura granite is a great and varied group of basic rocks, epidiorites and hornblende-schists, which on the evidence of a few local xenoliths discovered by Mr. J. B. Auden preserved in the Erinpura granite, are thought to have been in part basalt and monzonite; these metamorphics are particularly in force in the north-western flank of the synclinorium. Similarly ultra-basic rocks are believed to be represented by talc and chlorite schists south-west of Beawar, and by a number of small plugs of an unfoliated talc-limonite-serpentine rock with veins of magnesite, south of Ajmer.

The well-known syenites of Kishengarh (26° 34′ : 74° 55′) (Heron, 1924), with their remarkable pegmatites, are probably pre-Delhi in age. They are very restricted in areal distribution. At the other end of the Aravalli range in Sirohi is found an interesting suite of basic and ultra-basic rocks which also contains an example of sodalite-syenite, and comprises picrites, pyroxenites, gabbro, basalt and dolerite. These are later than the Erinpura granite, and earlier than the Malani series.

The Jalor (25° 22′ : 72° 35′) and Siwana (25° 40′ : 72° 25′) granites of La Touche, with their hypabyssal granophyres and porphyries, and effusive rhyolites, form the Malani series and have a great development to the west of the Aravalli range. They are the latest igneous rocks, with the exception of the dolerite, which cuts the Delhis, the Malani series, and even the Semri[1] series or Lower Vindhyans.

List of more important papers on Rajputana Geology.

Coulson, A. L.—Geology of Bundi State, Rajputana. *Rec. Geol. Surv. Ind.*, vol. 60, pt. 2, (1927).

Coulson, A. L.—The Geology of Sirohi State. *Mem. Geol. Surv. Ind.*, vol. 63, pt. 1, (1933).

Fermor, L. L.—Age of Aravalli Range. *Rec. Geol. Surv. Ind.*, vol. 62, pt. 4, (1930).

Ghosh, P. K.—Talc-Serpentine-Chlorite Rocks of Southern Mewar and Dungarpur. *Rec. Geol. Surv. Ind.*, vol. 66, pt. 4, (1933).

[1] J. B. Auden, *Mem. Geol. Surv. Ind.*, LXII, pt. 2, pp. 191–193, (1933).

GUPTA, B. C.—The Geology of Central Mewar. *Mem. Geol. Surv. Ind.*, vol. 65, pt. 2, (1934).

HACKET, C. A.—Arvali series in North-Eastern Rajputana. *Rec. Geol. Surv. Ind.*, vol. 10, pt. 2, (1877).

HACKET, C. A.—Useful minerals of the Arvali region. *Rec. Geol. Surv. Ind.*, vol. 13, pt. 4, (1880).

HACKET, C. A.—Geology of Arvali region, central and eastern. *Rec. Geol. Surv. Ind.*, vol. 14, pt. 4, (1887).

HERON, A. M.—Geology of North-Eastern Rajputana and Adjacent Districts. *Mem. Geol. Surv. Ind.*, vol. 45, pt. 1, (1917).

HERON, A. M.—Binna-Lalsot Hills in Eastern Rajputana. *Rec. Geol. Surv. Ind.*, vol. 48, pt. 4, (1917*a*).

HERON, A. M.—Gwalior and Vindhyan Systems in South-Eastern Rajputana. *Mem. Geol. Surv. Ind.*, vol. 45, pt. 2, (1922).

HERON, A. M.—Geology of Western Jaipur. *Rec. Geol. Surv. Ind.*, vol. 54, pt. 4, (1922*a*).

HERON, A. M.—Soda-rocks of Rajputana. *Rec. Geol. Surv. Ind.*, vol. 56, pt. 2, (1924).

HERON, A. M.—Vindhyans of Western Rajputana. *Rec. Geol. Surv. Ind.*, vol. 65, pt. 4, (1933).

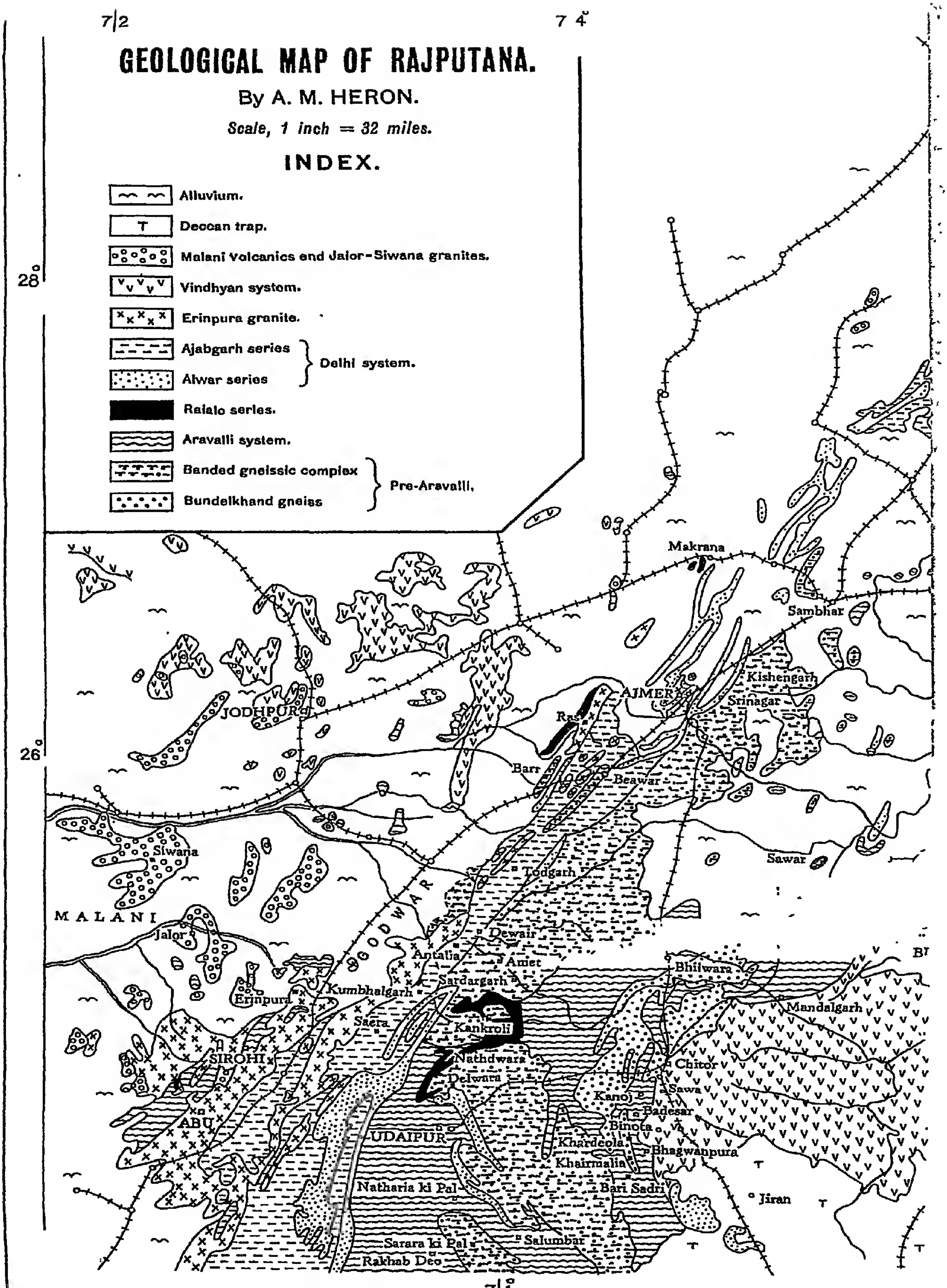
HERON, A. M.—The Mineral Resources of Rajputana. *Trans. Min. and Geol. Inst. Ind.*, vol. 29, pt. 4, (1935).

LATOUCHE, T. D.—Geology of Western Rajputana. *Mem. Geol. Surv. Ind.*, vol. 35, pt. 1, (1902).

MIDDLEMISS, C. S.—Geology of Idar State. *Mem. Geol. Surv. Ind.*, vol. 44, pt. 1, (1921).

SHARMA, N. L.—A Preliminary Note on the Geology of Danta State. *Q.J. Geol. Min. and Met. Soc. Ind.*, vol. 3, pt. 1, (1931).

Printed and Published by P. Knight, Baptist Mission Press, 41A, Lower Circular Road, Calcutta, for the National Institute of Sciences of India, 1, Park Street, Calcutta.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Trans. Nat. Inst. Sci. India, vol. , pp. , (1935).

India,—Air-breathing Fishes of.
Trans. Nat. Inst. Sci. India, vol. , pp. , (1935).

Evolution, Air-breathing habit in fishes—Probable mode of.
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